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Laparoscopic Surgery in Children - Anaesthetic Considerations

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Abstract

Laparoscopic surgery has several advantages over conventional surgery for the patient. An increasing number of diagnostic and surgical procedures are being done laparoscopic not only in adults but also in paediatric patients. In addition to the routine anaesthetic considerations for any surgical patient, the choice of the anaesthetic technique in patients undergoing laparoscopic procedures should consider the patient's underlying cardio respiratory functions induced by the pneumoperitoneum and carbon dioxide [CO₂] insufflations. This article describes the physiological alterations induced by laparoscopic procedures in children and the anaesthetic implications of laparoscopic in the paediatric patient population.

Introduction

Laparoscopic surgery, compared to conventional surgery, has many advantages for the patient, including smaller incisions, lesser postoperative pain, earlier oral intake, quicker mobilization, faster discharge and a better cosmetic effect.^{1,2} In recent years, there has been a considerable improvement in laparoscopic surgical techniques and equipments and this has led to an increasing number of diagnostic and surgical procedures being done laparoscopically not only in adults but also in paediatric patients. Ure and colleagues³ have reported a spectrum of 26 different surgical procedures being performed laparoscopically.

The common laparoscopically performed procedures in children include appendectomy, pyloromyotomy, diagnosis of contralateral inguinal hernia, cholecystectomy, gastric fundoplication etc.³ Several other laparoscopic procedures have been reported in the paediatric population including liver biopsy, cholangiograms, splenectomy, colectomy, nephrectomy, and rectal pull-through.^{1,3,4} In addition to the routine anaesthetic considerations for the individual patient, the choice of the anaesthetic technique in these patients should consider changes in haemodynamic and respiratory functions induced by the pneumoperitoneum and carbon dioxide (CO₂) insufflation.⁵ This article describes the physiological changes produced by laparoscopy in children and the anaesthetic considerations for laparoscopic procedures in the paediatric patient population.

Physiological Alterations Associated with Laparoscopic Surgery

The physiological changes associated with laparoscopic surgery result from the raised intraabdominal pressure (IAP) caused by the creation of pneumoperitoneum,

systemic absorption of the intraperitoneally insufflated CO₂, and the position of the patient during surgery. The anaesthesiologist should have a sound knowledge of the differences in the physiological effects produced in response to the CO₂ pneumoperitoneum in children compared to those in adult patients. Cardiorespiratory changes during laparoscopy have been studied widely in adult patients and, more recently, several studies have been performed to assess the cardiorespiratory changes in children during laparoscopic surgery^{1,3,5-17} as this type of surgery is gaining popularity among the paediatric surgeons.

Physiological Response to Raised Intra-abdominal Pressure

The IAP level is a major determinant of cardiorespiratory changes during laparoscopy. The cardiovascular response to an increase in intra-abdominal pressure involves changes in preload, systemic vascular resistance and myocardial contractility.^{6,7} A decrease in cardiac output (CO) may occur as a result of decreased venous return and an increase in systemic vascular resistance (SVR). The reduction in preload is dependent on the degree of increase in abdominal pressure.⁶ In adults, with minor increases in IAP (<15mmHg), there is an increase in venous return and cardiac output resulting from the displacement of blood from the splanchnic venous circulation.⁷ With intra-abdominal pressure of above 20mmHg, preload decreases while systemic vascular resistance increases. These factors lead to a decrease in cardiac output. The mean arterial pressure usually remains unchanged or even increases because of the increase in systemic vascular resistance.⁷

In the paediatric patient similar changes in the cardiovascular status have been seen at much lower IAP. Gueugniaud and colleagues studied the haemodynamic effects of pneumoperitoneum during laparoscopic surgery in healthy infants by continuous oesophageal aortic blood flow echo-doppler.⁸ The intra-abdominal pressure was maintained at 10mmHg. They found that the induction of pneumoperitoneum resulted in a significant decrease in aortic blood flow and stroke volume, and a significant increase in systemic vascular resistance, compared with controlled values. These changes had no clinically deleterious effects in healthy infants and were completely reversed after peritoneal decompression. Sakka and colleagues⁹ performed a transoesophageal echocardiographic assessment of haemodynamic changes during laparoscopic herniorrhaphy in small children at two different levels of IAP, 6 and

12mmHg. They found that the cardiac index (CI) decreased significantly after increasing IAP to 12mmHg but this decrease did not appear to be clinically important. Subsequent decrease in IAP to 6mmHg caused return of CI to baseline level and a further increase in IAP to 12mmHg did not cause any reduction in CI. Gentili et al.¹⁰ used echocardiography to look at the cardiac response to peritoneal insufflation in children and found significant increase in left ventricular end diastolic volume and end systolic volume. Ejection fraction was preserved and blood pressure and heart rate increased. The peak and mean airway pressures also increased. Tobias and colleagues⁷ found minimal cardiovascular changes in paediatric patients during laparoscopy in their study on the cardiorespiratory changes during brief laparoscopy in children. An increase in blood pressure was seen which probably resulted from an increase in systemic vascular resistance related to the increased IAP and the increased PaCO₂. In a retrospective paediatric study, it was found that arterial pressure increased only when IAP was higher than 6mmHg.¹¹ Huettemann et al.¹² found that at an IAP of 12mmHg, there was significant septal hypokinesia in paediatric patients undergoing laparoscopic surgery.

The overall cardiovascular changes associated with laparoscopic surgery depend upon the intra-abdominal pressure attained, the amount of CO₂ absorbed, the patient's intravascular volume status, the ventilatory technique, surgical conditions, and the anaesthetic agents used.¹³ Patient positioning, hypercarbia, and the use of positive pressure ventilation can further compromise the cardiovascular function. The anaesthesiologist should also be aware of the fact that vagally mediated reflex bradycardia or even asystole can occur during insufflation, especially in infants and small children¹⁴, and should be well prepared for any such event.

The increase in IAP also affects the respiratory function. There is a decrease in functional residual capacity (FRC) relative to the closing volume. This can lead to intrapulmonary shunting and hypoxaemia.¹⁵ In infants, a reduction of FRC due to the pneumoperitoneum and the consequent raised IAP causes alveolar collapse, increased venous admixture and oxygen desaturation more rapidly than in adults.¹⁵ Bannister and colleagues¹ studied the effects of IAP on pulmonary mechanics in infants undergoing laparoscopic surgery under general anaesthesia. They found that at insufflation pressure of upto 12mmHg for infants <5kg and upto 15mmHg for infants >5kg, average peak inspiratory pressure (PIP) increased 18%, average tidal volume (Vt) decreased 33%, average end-tidal CO₂ (PETCO₂) concentration increased 13%, average compliance decreased 48% and O₂ saturation fell in 41% of patients. Overall ventilator adjustments were made 20 times in this study. They concluded that the magnitude of change correlates directly with

intra-peritoneal pressure. Similarly, Bergesio et al.⁵ found that the peak pressure increased by 26.6%, resistance increased by 20.2% and the compliance decreased by 38.9% after peritoneal insufflation to 10-12mmHg in children aged 8 months to 11 years.

As the cardiorespiratory changes produced by raised IAP are seen at lower values in children, it has been recommended that the IAP produced by pneumoperitoneum should be limited to 5-10mmHg in toddlers and infants and to about 10-12mmHg in older children.¹³ The minimum setting of a typical insufflator is about 1L/min, which can be too great for a small child and extra care is required to prevent excessive IAP from developing. The rise in IAP can also lead to an increase in intracranial pressure (ICP). In one study Bloomfield and colleagues¹⁶ found that increasing the IAP to 25mmHg increased the ICP from a mean of 7.6 to 21.4mmHg and decreased the cardiac index and cerebral perfusion pressure from a mean of 82 to 62mmHg.

Physiological Alterations Produced by Carbondioxide Absorption and Patient Positioning

The absorption of carbondioxide from the peritoneal cavity leads to an increase in the end tidal CO₂ (PETCO₂) during laparoscopic surgery.⁷ This frequently requires an increase in the minute ventilation in children to compensate for the hypercarbia. Rowney and Aldridge¹⁹ found a median increase in PETCO₂ of 7.6mmHg in their experience with laparoscopic fundoplication. The hypercarbia can lead to further increase in systemic vascular resistance and myocardial depression.⁷ It can also cause sympathetic nervous system stimulation resulting in increased plasma catecholamines which may cause an increase in heart rate and blood pressure. The PETCO₂ rapidly returns to baseline within 10 minutes of completion of laparoscopy.¹⁹

Patient positioning can also compromise respiratory function. The Trendelenburg position along with the raised IAP decreases lung compliance. FRC is reduced by the Trendelenburg position while the reverse Trendelenburg position may improve respiratory compliance.²⁰ The cardiovascular system is also affected by the position of the patient. The venous return is increased by the Trendelenburg position whereas it decreases further by the reverse Trendelenburg position.

The physiological changes described above are usually well tolerated in patients with normal cardiovascular function, but may become significant in patients with underlying cardiovascular disorders. Bozkurt et al.²¹ studied the stress response to laparoscopy compared to laparotomy in children with acute abdominal pain and found no difference in the degree of rise in various stress hormones. Diffusion of CO₂ from the peritoneal cavity into the subcutaneous tissue,

or along the fascial planes into the mediastinum can occur occasionally leading to subcutaneous emphysema, pneumothorax or pneumomediastinum.²²

Thus contraindications for laparoscopic surgery include hypovolaemia, heart disease, raised intracranial pressure and alveolar distension. Gas-less laparoscopic procedures have been described²¹ where devices designed to tent the abdominal wall are used. This technique may be useful in small children and infants.

Management of Anaesthesia for Laparoscopy in Children

With the advent of new surgical approaches, there may also be a need for specific modifications in the anaesthetic technique. Although anaesthesia for laparoscopic surgery does not require a major extension of the usual anaesthetic technique for general abdominal surgery, special consideration must be given to the alteration in cardiorespiratory status that occurs due to the raised IAP, absorption of CO₂, and the patient positioning during the procedure. An understanding of the anticipated procedure combined with the knowledge of its effects on cardiorespiratory function will assist in planning the anaesthetic care.

A detailed history and physical examination should be undertaken preoperatively to identify any underlying medical conditions that may affect the perioperative management of the patient. Preoperative laboratory investigations depend upon the clinical condition of the patient. The haemoglobin and haematocrit levels are usually sufficient for most patients unless the patient has a significant systemic disease. Blood loss is usually minimal in laparoscopic surgery, but the anaesthesiologist must remember that a laparoscopy may be converted into a laparotomy. Therefore, in cases where the baseline haemoglobin is low or a major procedure is being performed laparoscopically, a sample should be taken for grouping and saving serum for urgent cross matching if required.¹⁴

An oral anxiolytic/sedative premedication is very useful in children and allows an easy separation from the parents. Atropine or glycopyrrolate may be included in the premedication in order to prevent the reflex bradycardia that can occur on abdominal insufflation, in addition to their effect of decreasing airway secretions. The choice of the induction agent and technique should be based on the clinical status of the patient. Induction of anaesthesia can be performed either by inhalational technique with sevoflurane or halothane in nitrous oxide and oxygen, or with one of the available intravenous induction agents. This is followed by a nondepolarizing neuromuscular blocking agent, such as atracurium or vecuronium, to facilitate endotracheal intubation and provide muscle relaxation for the surgical proce-

dure.

Anaesthesia is maintained with controlled ventilation with an inhalational agent such as isoflurane supplemented with an intermediate acting nondepolarizing neuromuscular blocking agent and intravenous opioids as required. Although general anaesthesia with endotracheal intubation (ETT) is the usual technique for laparoscopic surgery in children, the laryngeal mask airway (LMA) has been used safely for short procedures²³, and may be considered in patients with severe asthma in whom airway instrumentation needs to be avoided. Halothane should be avoided for maintenance, where possible, because the hypercarbia and the subsequent sympathetic stimulation that occurs due to CO₂ absorption from the peritoneal surface can cause arrhythmias when combined with halothane.^{14,24} Ventilation is usually needed to be increased by 15-30% during the procedure to compensate for the extra load of CO₂^{5,6} and positive end-expiratory pressure may be required to counter the effects of increased IAP on FRC.

Constant intraoperative monitoring of the patient's cardiorespiratory status is essential because of the various physiological alterations that can occur by gas insufflation. Monitoring should include continuous electrocardiogram, pulse oximetry, non-invasive blood pressure measurement, PETCO₂ measurement and temperature monitoring. A precordial stethoscope is useful in infants. Peak inspiratory pressure should also be watched closely. The PETCO₂ usually returns to normal within minutes of the removal of CO₂ from the peritoneal cavity.¹⁹ At the end of the procedure, residual neuromuscular blockade is reversed and the trachea extubated. Postoperative analgesia is best provided with a multimodal approach using a combination of local infiltration of the trocar insertion site, opioids and nonsteroidal anti-inflammatory drugs. Caudal epidural block has been demonstrated to be effective following inguinal herniorrhaphy with laparoscopy in children.²⁵ Postoperative nausea and vomiting can occur in children after laparoscopy¹⁴ and antiemetics should be prescribed for the postoperative period on an "as required" basis.

Conclusion

Laparoscopic surgery has found increasing applications in the adult patient population all over the world and it is reasonable to assume that it will do so in the paediatric patients. With minor modifications in anaesthetic technique and appropriate care, laparoscopic approach to surgical procedures has been shown to be safe even in the neonatal patient. The patient's underlying cardiorespiratory status, pre-existing medical conditions and the changes in cardiorespiratory physiology induced by laparoscopy should

be taken into consideration when planning the anaesthetic technique for these patients. The challenge of the future is appropriate application of these procedures while maintaining the child's safety as the foremost concern.

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